Real-Time Forecasting System of Winds, Waves and Surge in Tropical Cyclones

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14. ABSTRACT
The long-term goal of this partnership is to establish an operational forecasting system of the wind field and resulting waves and surge impacting the coastline during the approach and landfall of tropical cyclones. The results of this forecasting system would provide real-time information to the National Hurricane Center during the tropical cyclone season in the Atlantic for establishing improved advisories for the general public and federal agencies including military and civil emergency response teams.

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LONG-TERM GOAL

The long-term goal of this partnership is to establish an operational forecasting system of the wind field and resulting waves and surge impacting the coastline during the approach and landfall of tropical cyclones. The results of this forecasting system would provide real-time information to the National Hurricane Center during the tropical cyclone season in the Atlantic for establishing improved advisories for the general public and federal agencies including military and civil emergency response teams.

OBJECTIVES

1) To describe and define the functions and interfaces of the tropical cyclone forecasting system.

2) To determine the required data sources and data flow for initializing the models and providing boundary conditions.

3) To design a powerful, high-speed computing system with flexible architecture for optimal real-time model computations.

4) To define output products necessary to enhance the guidance skills of the Tropical Cyclone Forecast/Advisory product.

5) To test the model infra-structure that would lead toward better forecast information for landfall hurricane wind, wave, and surge conditions. Several historical storms will be used to assess model infra-structure.

6) To develop the interface that couples high-resolution cyclone wind fields to the selected wind model.

7) To develop a system that couples storm surge and spectral wave models driven by winds specified in 6).

8) Test entire system via a proof-of-concepts approach with data from several historical hurricanes.

9) Test system in semi-operational mode during several hurricane seasons and begin transition to fully operational mode.

APPROACH

The estimation of tropical cyclone-generated waves and surge in the coastal waters and nearshore zone is of critical importance to the timely evacuation of coastal residents, and the assessment of damage to coastal property in the event that a storm makes landfall. The model predictions of waves and storm surge in coastal waters are functionally related and both depend on the reliability of the atmospheric forcing. In the nearshore region we can only rely on simple parametric wind models where only storm surge still water levels are being computed. In most cases, these simple wind fields result in poor estimators of storm surge winds and hence surge-induced water levels because the hurricane's actual wind field often differs significantly from the model wind.

Model Grids: The ocean wave model WAM will be implemented on a basin scale (~25 km) grid over the entire North Atlantic and Caribbean Basins, and Gulf of Mexico. In the coastal and nearshore regions we will utilize nested high-resolution (< 5 km) grids to include shallow water effects such as shoaling, refraction and dissipation by bottom friction. For the storm models we will use finite element grids based on one arc-second high resolution bathymetry (Figure 1). From this a finite element grid has been generated with over 350,000 elements that range in size from tens of kilometers to just a few meters near the coast (Figure 2).

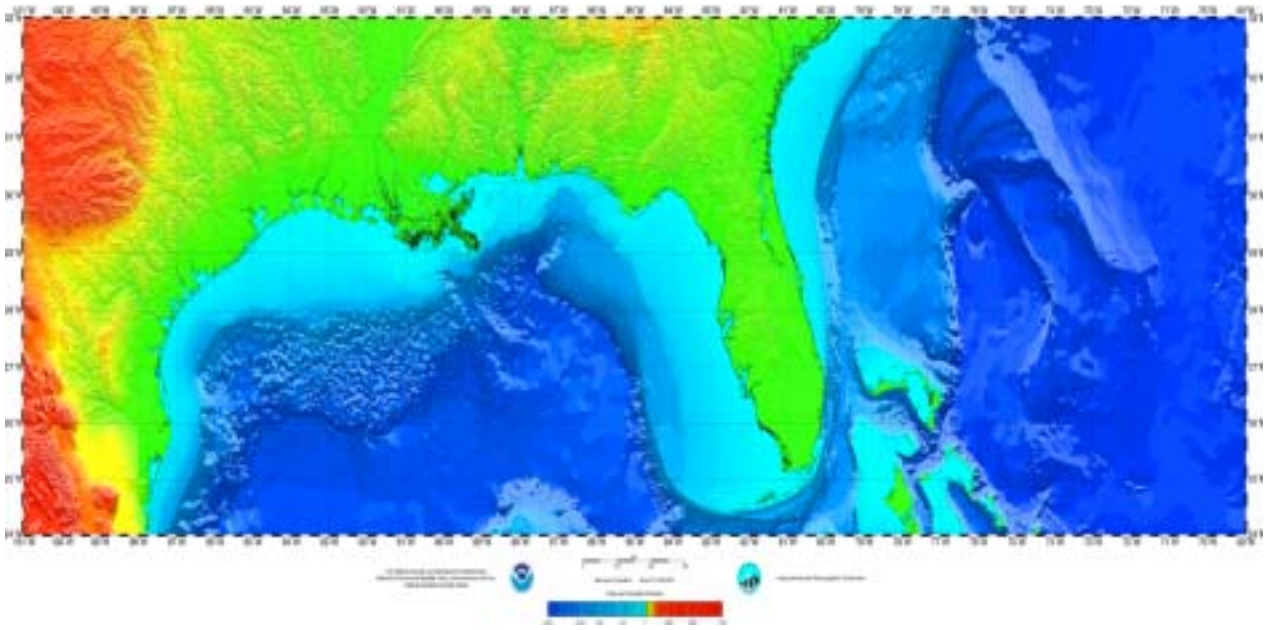

Figure 1: High-resolution 1-arc second bathymetry data for use in grid generation of the wave and storm surge models.

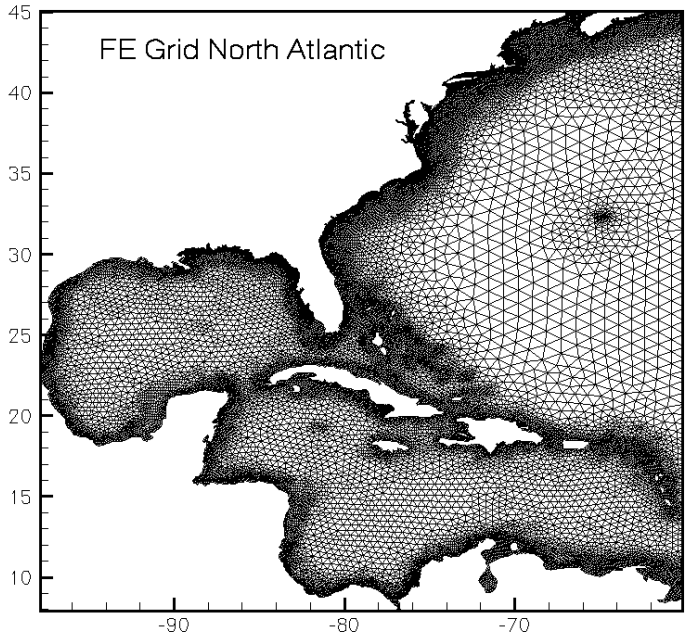

Figure 2: The finite element grid of the storm surge model for the western North Atlantic, the Caribbean and the Gulf of Mexico based on the bathymetry data shown in Figure 1.

Wind Fields: The use of snapshots of tropical cyclone wind fields, such as those routinely available in real-time to forecasters at the National Hurricane Center will become the basis for the wind analysis system. These winds have been applied directly to tropical and extra-tropical wave model simulations with success. Recently the interactive objective kinematic analysis (IOKA) methodology became available that is capable to evolve in space and time the sub- and mesoscale features in a developing cyclone such as surface wind jet streaks. With a high degree of success, the use of these wind fields in wave prediction models produced unprecedented accuracies in the hindcasted skill of storm peak wave heights in extratropical storms (Cardone *et al*. 1995) and tropical storms (Cardone *et al*. 1996). The two sets of wind fields will be generated that complement each other and represent the detailed structure and dynamics of tropical cyclones. Both sets of wind fields must be interchangeable for times when no in-situ measurements might be available and for simulating waves and surge along the different paths from the suite of track prediction models maintained by the National Hurricane Center. The gridded winds of the snapshots are then temporally interpolated using the IOKA methodology to retain the relative energetics of tropical cyclones, as well as continuity of the winds (Figure 3).

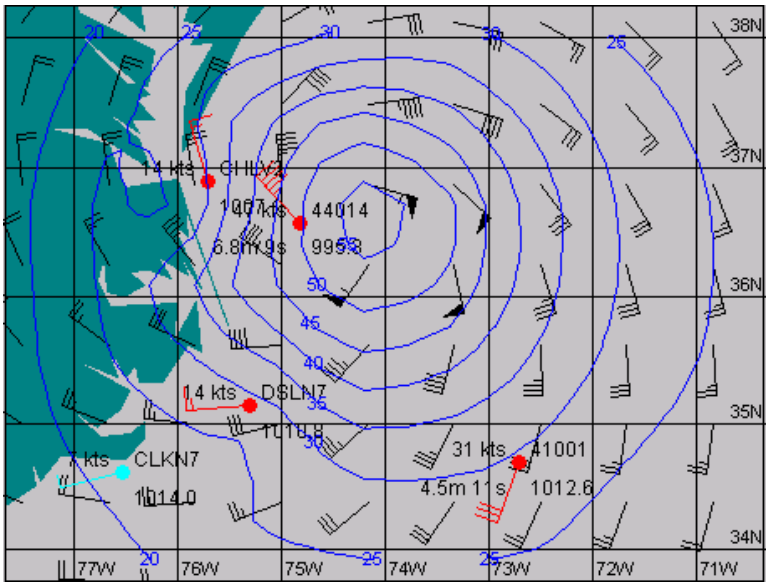

Figure 3: Example of the final IOKA wind field with the incorporation of tropical vortex winds. The black wind vectors are the model winds and the red ones are observations. The blue lines show isotachs in 5 m/s increments.

Wave Prediction: Wave predictions were made with both the IOKA and HRD produced wind fields. For the Hurricane Georges test case, using either HRD or IOKA winds, the wave model simulations performed very well over the entire Gulf of Mexico domain as well as within the range of tropical force winds of Georges. Additional tests will be performed for other historical hurricanes such as Floyd, Bonnie, Andrew and Opal.

Storm Surge: The surge model ADCIRC has been implemented on the North Atlantic grid shown in Figure 2 and is forced with either the HRD and IOKA wind fields. Presently the version of ADCIRC used here does not explicitly have flooding and drying capability of low-lying land, however, it can dry water nodes and then re-flood them. This option will be important especially over the barrier islands and low-lying coastlines for the correct calculation of combined wave/surge effect and for high water marks. A series of simulation with the storm surge model will be conducted for the different historical storms as well as exploring the usefulness of the model for small embayments and river mouths.

This project will establish a "node" to develop an integrative coastal model for storm wind, wave and surge predictions. In YR 1 the forecasting system will be implemented and fully tested to ensure data flow and computational efficiency. In YR 2 and 3 prototype testing will commence in a semi-operational phase. Output will be provided on a contingency basis subject to evaluation and assessment. In YR 4 and 5 we expect to perform with full operational capability. The timeliness and value of the deterministic and probabilistic output products would be evaluated during the entire hurricane season.

WORK COMPLETED

This project has just started and current activities were limited to acquiring a computer for the project. IBM, one of the partners in this project, is providing equipment and computational support and expertise to process and refine the massive amounts of data that are generated in the forecasting effort. The new IBM eServer p690 supercomputer, code-named "Regatta," has been installed at the University of Miami and the various model codes have been installed and tested. The supercomputer is one of IBM's most advanced implementation of the powerful UNIX operating system. This is the first supercomputer of its type to operate in South Florida and the University of Miami will be housing one of only four others currently in the state.

RESULTS

Projected just began. No new results yet.

IMPACT/APPLICATION

The expected results of the real-time forecasting system for winds, waves and surge in tropical cyclones promise to provide in a timely manner critical information to the National Hurricane Center for better advisories and warnings to local, state and federal emergency agencies and the general public. The challenge of crisis managers and emergency planners is to relocate an ever-increasing coastal population from the path of destructive tropical cyclones.

TRANSITIONS

None yet.

RELATED PROJECTS

Modelling the wave field in shallow water and coastal regions is one of the primary objectives of the Shoaling Waves Experiment (SHOWEX). From the experimental phase we expect to find improved source term definitions for waves in shallow water which we would implement for the real-time forecasting system.

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